SURGE DETECTOR FOR TURBINE ENGINES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to turbine engines, and particularly to a method and apparatus for sensing when the engine is operating near a surge or stall condition. The present invention senses the imminence of off idle stall and fan surge in the fan or compressor portion of the engine prior to a complete engine airflow breakdown. By anticipating or sensing the onset of surge, corrective action can be taken to avoid the actual stall or surge condition thereby prolonging engine life, preventing severely degraded engine performance and adding to the operational safety margin of aircraft utilizing turbine engines. Superior performance can also be realized from a turbine engine which, because of the protection afforded by the method and apparatus of this invention, may be operated at minimum surge margin.

The method and apparatus of this invention may also be applied advantageously to nonflight turbine engines and/or fan and compressor rig testing during which intentional surges must be induced to define and document the surge line. By identifying the point of surge imminence, yet avoiding the mechanical and/or aerodynamic loading imposed by the surge condition, much more data and longer hardware life can be realized.

2. Description of the Prior Art

The present invention is an improvement over the near surge indicator for turbine engines which is described and claimed in U.S. patent application Ser. No. 400,307 and entitled "Near Surge Indicator for Turbine Engines" filed Sept. 24, 1973, now U.S. Pat. No. 3,868,625, and assigned to the same assignee as the present application. In the prior application a pair of pressure sensitive transducers are connected to pressure probes positioned in an engine flow path such as the fan discharge path of a turbofan engine. One of the pressure transducers is a high response device sensitive to a frequency range such as 0 to 1,000 Hz. The output from the high response transducer is passed through a band-pass filter to isolate the frequencies of interest, approximately 10 to 250 Hz, and to attenuate the pressure oscillation frequencies outside this range. The other of the transducers is a low response device which responds only to low pressure frequencies. The output from the low response transducer is passed through a low-pass filter to attenuate all frequencies above about one-fourth Hz and pass therethrough only low frequencies equivalent to the steady state absolute pressure level. The ratio of the amplitudes of the high frequency pressure oscillations to the steady state signal is electronically computed in a ratio calculator and this ratio is continuously compared with a predetermined reference ratio in a comparator circuit. If the computed ratio is higher than the reference ratio, the imminence or existence of surge condition is signalled and corrective action may be taken or a warning signal may be produced.

The actual onset of surge may also be sensed as described in the above-identified patent application by passing through the high response transducer frequencies in the 10–90 Hz range and modifying the predetermined ratio accordingly.

The present invention is an improvement on the teachings of the above-identified patent application and utilizes the same basic principle that off idle stall and fan surge are preceded by an increase in high frequency pressure fluctuations in the airstream behind the fan. In the prior application the high frequency pressure fluctuations show a distinctive signature which can be used to warn of incipient surge and to automatically activate surge avoidance procedures.

In present-day turbine engines, the pressure levels that must be sensed range from 3 to 100 psi. It has been found that for best results with the near surge indicator described in the above-identified application, the useful signal range is from 3 to 20 psi. Typical pressure sensors presently available have an accuracy capability of plus or minus 2 percent of full scale so that even at the highest pressures which occur in the engine, the pressure can be sensed only to an accuracy of plus or minus 2 psi. At very high altitudes, the pressure can be as low as 3 psi, and in this case the accuracy of the output from the pressure sensors is relatively poor. Furthermore, the apparatus described in the prior application requires the computation of a ratio of the amplitudes of the high frequency pressure oscillations to the steady state pressure, and the accuracy of this ratio computation is severely decreased at low pressures.

SUMMARY OF THE INVENTION

The present invention overcomes the limitations of the prior art by removing the signal ratio calculation and producing in place thereof a trigger level as a function of the steady state pressure. The high frequency pressure fluctuations are compared with the trigger level, and high frequency pressure fluctuations which exceed the trigger level are indicative of the imminence of off idle stall or fan surge. This improvement allows more reliable operation at the low pressure levels associated with high altitude and part power conditions.

In accordance with a preferred embodiment of the present invention, a pair of pressure transducers are connected to pressure probes positioned in a flow passage of a turbofan engine downstream of the fan and respond to the pressure fluctuations which occur in the airstream. One transducer has a high response capability, and its output is passed through a band-pass filter to isolate the high frequencies of interest. The other transducer has a low response capability, and its output is passed through a low-pass filter to provide a steady state pressure level. The steady state pressure level is used to schedule a triggering level which is then compared with the high frequency signal produced in the band-pass filter. If the amplitude of the high frequency pressure signal is greater than that of the triggering level, the engine is approaching a surge or stall condition, and a warning signal may be generated which can act as an alarm, or which may be used to institute corrective action.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic of a turbofan engine showing the installation of pressure sensitive transducers and their connection to the improved near surge indicating system.

FIG. **2** is a graph showing the triggering level generated in FIG. **1** as a function of steady state pressure.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. **1** there is shown in schematic form a portion of a typical axial flow turbofan engine **10.** In turbofan